Southern African Society for

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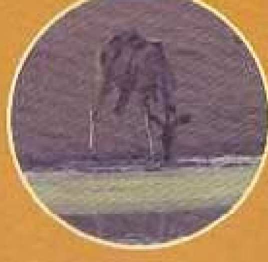

PROCEEDINGS

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A METHOD FOR ESTIMATING THE DISTRIBUTION OF SPECIES SUSCEPTIBLE TO FOOT-AND-MOUTH DISEASE IN THE KRUGER NATIONAL PARK REGION

D.P. Brahmbhatt, G. Fosgate[1], B. Gummow[2], M. P. Ward[1], V. Vosloo[3,4], F. Jori[5], C. Budke[1], R. Srinivasan[6], L. Highfield[1]

SUMMARY

Landscape distribution of susceptible species is needed to model the spatial spread of infectious diseases. Our objective is to develop 2 individual species animal count maps – for African buffalo and domestic cattle susceptible to foot-and-mouth disease (FMD) in the Kruger National Park Region (KNPR) of the Republic of South Africa (RSA) – using retrospective census and land use data. The KNPR includes the Kruger National Park, Limpopo and Mpumalanga provinces. We applied dasymetric mapping methods to disaggregate animal population census data to a finer resolution using ancillary data. In this study, ancillary data used to define species distributions included stocking rate or carrying capacity and land suitability parameters. A geographical information system (GIS) was used to identify suitable land and vegetation locations (x,y coordinates) for each species. Covariate-specific animal counts were modelled using a Poisson distribution. The resulting animal count data was mapped and will be used to model FMD spread within the KNPR.

INTRODUCTION

Information concerning the landscape distribution of susceptible species is necessary to model the spatial spread of infectious diseases. The Kruger National Park Region (KNPR) is vital for surveillance of infectious diseases because the continuous interaction between human, wildlife and livestock creates potential for their transmission. For the purpose of this study the KNPR is defined to include the Kruger National Park (KNP), Limpopo and Mpumalanga provinces in the Republic of South Africa (RSA) as shown

[1]Department of Veterinary Integrative Biosciences, Texas A&M University, College Station, Texas, 77843, USA.
[2]Epidemiology Division, Department of Production Animal Studies, Onderstepoort Faculty of Veterinary Science, University of Pretoria, South Africa.
[3]Exotic Diseases Division, Onderstepoort Veterinary Institute, Onderstepoort, South Africa.
[4]Department of Tropical Veterinary Diseases, Faculty of Veterinary Sciences, University of Pretoria, South Africa
[5]UPR Epidemiology, BIOS Department, Centre de coopération internationale en recherche agronomique pour le développement, France.
[6]Department of Forest Sciences, Texas A&M University, College Station, Texas, 77843, USA.

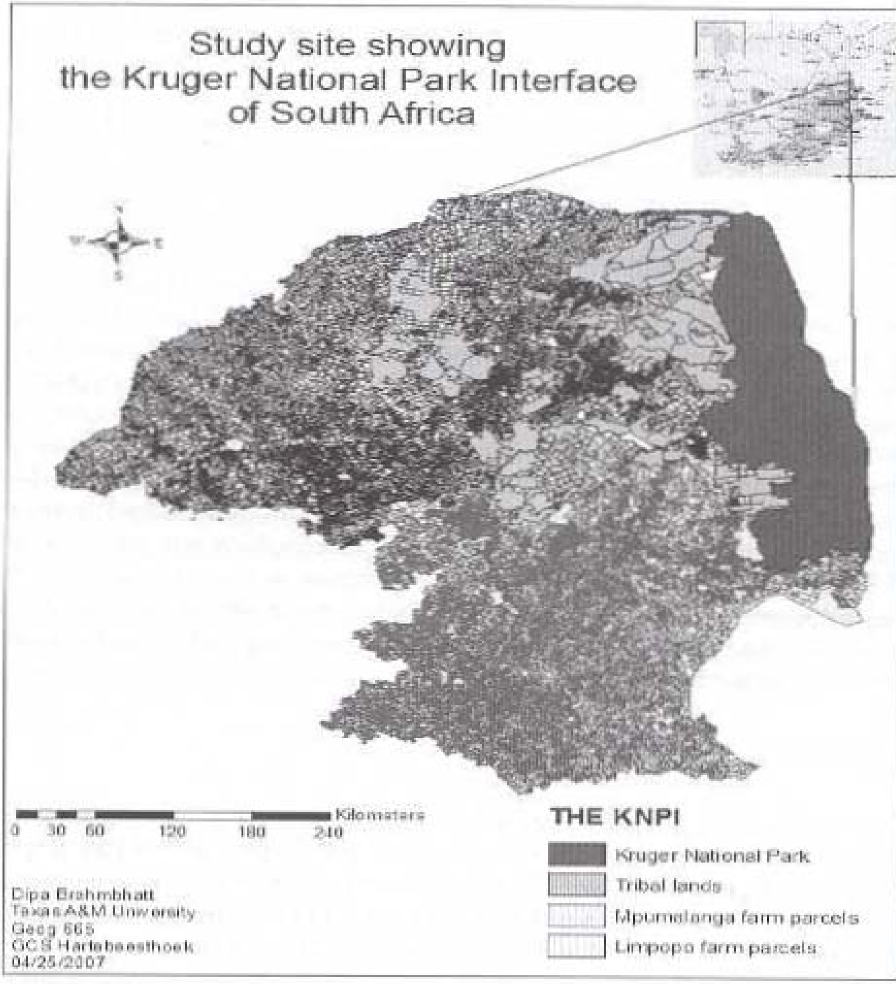

Figure 1: The Kruger National Park Region showing the Kruger National Park, Limpopo and Mpumalanga Provinces of RSA included in this study.

in figure 1. The KNP is separated from the provinces by a fence on its western boundary which is approximately 400 km in length. One of the infectious diseases of greatest concern in the KNPR is foot-and-mouth disease (FMD) which is a highly contagious, but rarely fatal viral disease affecting cloven hoofed wildlife and domestic livestock.

A number of wildlife species in Africa have been shown to be affected by FMD such as the African buffalo (*Synercus caffer*)and (*Aepyceros melampus*) in the KNP , and wildebeest (*Connochaetes taurinus*) in the Serengeti . Infected African buffalo are considered a source of FMD for susceptible livestock close to the KNP and impala in the KNP . Impala can act as intermediaries for the transmission of FMD virus from buffalo to cattle which could be due to their ability to jump perimeter fences . Phylogenetic analyses of outbreaks in cattle and impala caused by SAT 1 strains between 1971-1981 in the RSA indicated that several of the outbreaks had spread from impala to cattle . In addition, epidemiological investigations into the outbreaks in cattle in 2000, caused by SAT 1 and the SAT 2 outbreak in 2001 were traced back to buffalo that escaped from KNP. The exact mechanisms and spatial factors responsible for disease transmission to domestic animals remain unclear.

One of the limitations of modelling the distribution of susceptible species on a landscape is that the available census data is typically at an aggregate level. In the RSA this is available in the form of choropleth maps at district levels per province. Some of the limitations of these maps include smoothing the variations of local domestic cattle distributions, representing artificial transitions in domestic cattle counts at district boundaries and suggesting that cattle are distributed homogenously in the district even though some areas have no livestock .

The objective of this study is to develop methods to estimate the distribution of FMD susceptible species (domestic cattle and African buffalo) in the KNPR and further use this data to model the spread of FMD in the KNPR of the RSA.

MATERIALS AND METHODS

The dasymetric method was modified (S. Rollo, L. Highfield & M. Ward, unpublished data) by randomly allocating points on selected areas followed by disaggregating data using a Poisson distribution and varying stocking rates.

Retrospective Ancillary Data

The distribution of animal species can be approximated using vector based dasymetric mapping methods defined as using additional information to disaggregate coarser resolution population data to finer resolution . This method was modified by including a Poisson distribution (S. Rollo, L. Highfield & M. Ward, unpublished data). The additional information necessary to disaggregate census data was stocking rate (livestock) for commercial and communal farmers/ carrying capacity (wildlife), river network and vegetation layers. The stocking rate is defined as the number of animals per square kilometre and was calculated using 2004 census data acquired from National Veterinary Services (NVS). Commercial farmers differ from communal farmers because they have defined boundaries around their land, exclusive rights for the properties and produce competitively for export markets in the RSA. On the other hand, most communal farmers are primarily subsistence farmers, have undefined boundaries and generally have open access rights to defined grazing areas . The spatial commercial farm parcels, communal lands and river network for Limpopo and Mpumalanga provinces in 2000 were acquired from the NVS. The wildlife census was acquired from South African National Parks (SANPARKS). This consisted of the 2001 African buffalo mega herbivore census data for the entire KNP.

The 2004 South African National Biodiversity Institute (SANBI) vegetation map for RSA, Swaziland and Lesotho was acquired from the Department of Environmental Affairs and Tourism (DEAT). This vegetation map consists of 441 vegetation types which are classified into 9 major biomes representing large natural areas defined by vegetation type and climate . The 9 biomes are named as follows Albany thicket, desert, forest, grassland, Nama-Karoo, savanna, succulent Karoo and wetlands. All Geographic Information Systems (GIS) data was available as vector files with a scale of 1:50000.

Data Management in ArcGIS

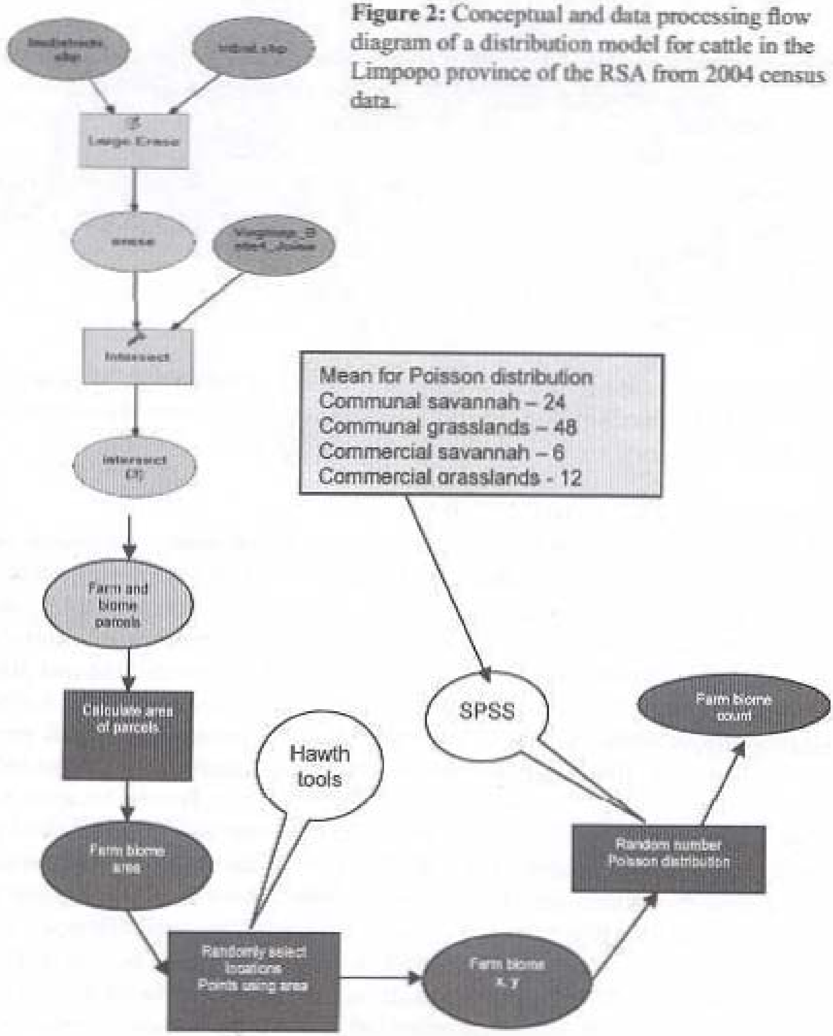

Figure 2: Conceptual and data processing flow diagram of a distribution model for cattle in the Limpopo province of the RSA from 2004 census data.

All the tasks for managing the data were done in ArcGIS . The land parcels for Limpopo and Mpumalanga provinces were projected the same as the vegetation layers. There were 28,183 farm parcels in Limpopo province. From these, 376 parcels which had no farm names were excluded. Some commercial land parcel boundaries were overlapping with communal lands and were erased from the communal lands. This resulted in two separate farm specific layers; one for commercial parcels and another for communal lands as shown in the top part of figure 2 using X-pro tools extension in ArcGIS. The stocking rates for commercial and communal lands extracted from the process above were calculated in Excel using 2004 census data.

The 2001 mega herbivore file for African buffalo was projected to UTM Zone 36 South (WGS 84). The data consisted of bull buffalo (single bulls and herds of bulls) and buffalo herd (total which includes calves) on latitude and longitude point locations in the KNP.

Geoprocessing

The commercial parcels were intersected with the vegetation layer in ArcGIS. Intersection results in a polygon with intersecting boundary and area between the commercial parcels and vegetation layer. The 47 different vegetation types in Limpopo province were reclassified into 4 major biomes (savannah, grasslands, forests and wetlands) using the South African National Biodiversity Institute classification scheme . The areas of each of these biomes which intersected with commercial parcels were calculated. Geographic locations were randomly selected using hawth tools extension in ArcGIS. These points were exported to SPSS where the Poisson distribution was used to model counts of cattle at each location. The mean for the Poisson distribution was determined using stocking rate information calculated for commercial and communal lands.

Grasslands have a high biodiversity and is important for dairy, beef and wool production in South Africa hence we assumed that it has a higher stocking rate than savannah biomes. The above procedure was repeated for communal farm parcels. The conceptual and data processing flow diagram is shown figure 2.

The procedure was based on the assumption that there were no cattle distributed in forests and wetlands because they are unsuitable biomes. Grasslands were considered the most suitable biome for grazing and the stocking rate was doubled for this biome. It was also assumed that the Poisson distribution was adequate to describe the distribution of cattle in the Limpopo province.

In the winter season (April to September) the African buffalo have been shown to not go further than 1 kilometre from water sources . This information was used to create seasonal maps for bull buffalo and buffalo herds in winter (April to September) and summer (October to March). The bull buffalo and buffalo herds were overlapped with the river network for the KNPR. The distance from each point to the rivers was calculated by joining the buffalo data files with the spatial attributes of the river. The maximum distance from the buffalo to the river shown in table 1 was used as a snap threshold for distributing census data to the river network in the KNP. The census points were snapped to rivers using hawth tools extension in ArcGIS. A snap threshold of 10 and 8 kilometres was used for bull buffalo and buffalo herd respectively.

Table 1: Descriptive statistics for the distance between buffalo locations and the closest river for bull buffalo and herds of buffalo.

DISTANCE to nearest RIVER (kilometres)	BULL BUFFALO	BUFFALO HERD
Mean	1.82	2.01
Median	1.03	1.66
Standard Deviation	1.91	1.54
Minimum value	0.07	0.24
Maximum Value	10.00	7.54

In the African buffalo distribution maps the assumptions are that there is no known migratory pattern data or population growth pattern model available for African buffalo, African buffalo shifts are seasonal where in the winter they do not go further than 1 kilometre from water sources, and the impact of the transfrontier conservation areas and re-distribution of wildlife species is not accounted for in the model.

PRELIMINARY RESULTS AND DISCUSSION

The area of commercial parcels was 73593.56 square kilometres and had 430 906 cattle (2004 census) giving a stocking rate of approximately 6 cattle per square kilometre. The area of communal lands was 27021.70 square kilometres and had 637 182 cattle (2004 census) giving a stocking rate of approximately 24 cattle per square kilometre. The stocking rate for savannah was approximated to 6 for commercial parcels and 24 for communal lands. We assumed that grasslands would have double the stocking rate of savannah. The maps are not presented here because they may affect subsequent publication in peer review journals. The resulting maps can be used to identify geographic locations with highest counts for cattle and African buffalo. This is important because locations with high counts of livestock may have higher economic losses during FMD outbreaks. The resulting maps can also be used in transmission models to evaluate spatial and temporal extent of the outbreak.

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REFERENCES

Bastos, A.D., Boshoff, C.I., Keet, D.F., Bengis, R.G. & Thomson, G.R. (2000) Natural transmission of foot-and-mouth disease virus between African buffalo (*Syncerus caffer*) and impala (*Aepyceros melampus*) in the Kruger National Park, South Africa. *Epidemiol. Infect.* 124: 591-598.

Bredenkamp, G., Grannger, J.E. &, van Rooyen, N. (1996) Vegetation of South Africa, Lesotho and Swaziland. In A companion to the Vegetation Map of South Africa, Lesotho and Swaziland, Barrie Low, A., Robelo, G., eds. (Pretoria, Department of Environmental Affairs and Tourism).

Bruckner, G.K., Vosloo, W., Du Plessis, B.J., Kloeck, P.E., Connoway, L., Ekron, M.D., Weaver, D.B., Dickason, C.J., Schreuder, F.J., Marais, T. & Mogajane, M.E. (2002) Foot and mouth disease: the experience of South Africa. *Rev. Sci. Tech.* 21: 751-764.

Dorling, D. (1993) Map design for census mapping. *The Cartographic Journal* 167-183.

Eicher, C.L. & Brewer, C.A. (2001) Dasymetric mapping and areal interpolation: Implementation and evaluation. *Cartography and Geographic Information Science* 28: 125-138.

ESRI (2005) ArcGIS.

Estes, R. (1991) The behavior guide to African mammals including hoofed mammals, carnivores, primates. University of California Press, Berkeley.

Hargreaves, S.K., Foggin, C.M., Anderson, E.C., Bastos, A.D., Thomson, G.R., Ferris, N.P. & Knowles, N.J. (2004) An investigation into the source and spread of foot and mouth disease virus from a wildlife conservancy in Zimbabwe. *Rev. Sci. Tech.* 23: 783-790.

Keet, D.F., Hunter, P., Bengis, R.G., Bastos, A. & Thomson, G.R. (1996) The 1992 foot-and-mouth disease epizootic in the Kruger National Park. *J. S. Afr. Vet. Assoc.* 67: 83-87.

Mucina, L. & Rutherfors, M. (2004) Vegetation map of South Africa, Lesotho and Swaziland: shapefiles of basic mapping units (Cape Town, South Africa, National Botanical Institute).

Palmer, T. & Ainslie, A. (2002) Country Pasture / Forage Resource Profiles - South Africa. In Country Pasture / Forage Resource Profiles (FAO Crop and Grassland Service (AGPC)).

Rouget, M., Reyers, B., Jonas, Z., Desmet, P., Driver, A., Maze, K., Egon, B. & Cowling, R. (2004) South African National Spatial Biodiversity Assessment 2004 Technical Report Volume 1: Terrestrial Component.

Ryan, S.J., Ryan, S.J., Knechtel, C.U. & Getz, W.M. (2006) Range and Habitat Selection of African Buffalo in South Africa. *Journal of Wildlife Management* 70: 764.

Stuart, C. & Stuart, T. (1999) Field guide to the mammals of southern Africa. Ralph Curtis Books Pub., Sanibel Island, Fla.

Sutmoller, P., Thomson, G.R., Hargreaves, S.K., Foggin, C.M. & Anderson, E.C. (2000) The foot-and-mouth disease risk posed by African buffalo within wildlife conservancies to the cattle industry of Zimbabwe. *Prev. Vet. Med.* 44: 43-60.

Thomson, G.R. (1994) Foot and Mouth Disease, In: Coetzer, J.A.W., G.R. Thomson, R.C. Tustin, N.P.J. Kriek (Ed.) Infectious diseases of livestock with special reference to southern Africa. Oxford University Press, Cape Town, pp. 825-952.

Vosloo, W., Bastos, A.D. & Boshoff, C.I. (2006) Retrospective genetic analysis of SAT-1 type foot-and-mouth disease outbreaks in southern Africa. *Arch. Virol.* 151: 285-298.

Vosloo, W., Boshoff, K., Dwarka, R. & Bastos, A. (2002) The possible role that buffalo played in the recent outbreaks of foot-and-mouth disease in South Africa. *Ann. N. Y. Acad. Sci.* 969: 187-190.

Vosloo, W. & Thomson, G.R. (2004) Natural Habitats in Which Foot-and-Mouth Disease Virus is Maintained, In: Sobrino, F.E.D. (Ed.) Foot and Mouth Disease: Current Perspectives. Horizon Bioscience, Norfolk, pp. 383-410.

Wright, J.K. (1936) A method of mapping densities of population with Cape Cod as an example. *Geographical Review* 26: 103-110.